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Density structure of the cratonic mantle in Siberia, correlations with mantle petrology and kimberlite distribution

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We present a new regional model for the density structure of the cratonic lithospheric mantle in the Archean–Proterozoic Siberian Craton [1] and discuss it in relation to regional tectonic evolution, geochemical data on kimberlite-hosted mantle xenoliths, and data on kimberlite ages and distribution. The nearly isostatic balance of the Siberian Craton allows us for applying the free-board modeling to calculate the density structure of the lithospheric mantle beneath the Craton. Availability of the reliable regional crustal model [2] and the thermal model of the lithospheric mantle secures high reliability of free-board modeling, with the overall uncertainty of mantle density better than 0.02 g/cc or better than ca. 0.6% with respect to primitive mantle.

The free-board modeling provides a vertically-averaged mantle density in the layer from the Moho down to base of the chemical boundary layer (CBL). The depth extent of the CBL is debated, and while geophysical studies suggest that it may extend down to the LAB, xenolith-based studies from different cratons worldwide suggest that the correlation between CBL and LAB may be complex. We perform the analysis of the density structure of the cratonic lithospheric mantle for two models of the CBL thickness. Model 1 assumes that the base of the CBL coincides with the LAB and is laterally variable within the Siberian craton, whereas in Model 2 the base of the CBL is fixed at a 180 km depth, and the layer below 180 km depth down to the LAB is ascribed fixed, nearly fertile, density value.

The results, calculated at in situ and at room temperature (SPT) conditions, indicate a heterogeneous density structure of the Siberian lithospheric mantle with a strong correlation between mantle density variations and the tectonic setting. For Model 1, the lithospheric mantle is significantly less depleted than in Model 2, in particular in regions with deep lithospheric keels, whereas there is little difference between the two models for intracratonic sedimentary basins where the lithosphere thickness is less than 180 km. Three types of cratonic mantle are recognized from mantle density anomalies, and we report here the values calculated for two-layer Model 2, which is supported by petrologic data.
1) 'Pristine' cratonic regions not sampled by kimberlites have the strongest depletion with density deficit of 1.8–3.0% (and SPT density of 3.29–3.33 g/cc as compared to 3.39 g/cc of primitive mantle).
2) Cratonic mantle affected by magmatism (including the kimberlite provinces) has a typical density deficit of 1.0–1.5%, indicative of a metasomatic melt-enrichment.
3) Intracratonic sedimentary basins have a high density mantle (3.38–3.40 g/cc at SPT conditions) which suggests, at least partial, eclogitization. Moderate density anomalies beneath the Tunguska Basin imply that the source of the Siberian LIP lies outside of the Craton.

In situ mantle density is used to test the isopycnic condition of the Siberian Craton. Both CBL thickness models indicate significant lateral variations in the isopycnic state, correlated with mantle depletion and best achieved for the Anabar Shield region and other intracratonic domains with a strongly depleted

mantle. A comparison of synthetic Mg# for the bulk lithospheric mantle calculated from density with Mg# from petrological studies of peridotite xenoliths from the Siberian kimberlites
suggests that melt migration may produce local patches of metasomatic material in the overall depleted mantle.

References:

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[2] Cherepanova Y. et al. (2013) Tectonophysics, 609, 154-183.